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SEMI-ANNUAL PROGRESS REPORT

(1 December 1980 - 1 June 1981)

to

National Aeronautics and Space Administration

on

NASA Grant NSG-3264

Entitled

"THE BOUNDARY LAYER ON COMPRESSOR CASCADE BLADES"

Submitted by:

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A. INTRODUCTION

The purpose of NASA Research Grant NSG-3264 is to characterize the flow field about an airfoil in cascade at a Reynolds number of 5×10^5. The program is experimental and combines hot wire and laser anemometry with flow visualization techniques in order to obtain detailed flow data (e.g., boundary layer profiles, points of separation, and the transition zone] on a cascade of relatively highly loaded blades. The information provided by this study is to serve as benchmark data for the evaluation of current and future predictive models, in this way aiding in the compressor design process.

NASA Grant NSG-3264 is envisioned as a four year program. During the first year, the feasability of the proposed research is to be demonstrated by successfully testing both the experimental techniques and the data acquisition/reduction system. In the second year, these techniques are to be applied to define the flow field over a relatively heavily loaded airfoil in cascade. In subsequent years, the influence of variation of incidence angle and turbulence intensity are to be assessed.

This report summarizes the second year's research activity for the period 1 December 1980 to 1 June 1980. Progress made from 1 June 1979 to 30 November 1980 was presented in References [1], [2] and [3].

B. INITIATION OF PROGRAM

NASA Grant NSG-3264 was initiated on 1 June 1979. Dr. I. Kubo, principal investigator, left the Applied Research Laboratory of The Pennsylvania State University (ARL/PSU) on 28 September 1979. Dr. S. Deutsch joined the ARL/PSU staff on 12 November 1979 and assumed principal responsibility for the grant. In order to account for the delay produced by this personnel change, a six month contract extension was requested and granted. The extension was effective beginning 31 May 1980. With the extension included, the contract is currently on schedule. Second year funding was received in November 1980.

C. PROGRESS IN THE PERIOD 1 DECEMBER 1980 TO 1 JUNE 1981

1. Continuation of Flat Plate Boundary Layer Measurements

Reference [3] reports comparisons among total head tube, hot wire anemometer and laser anemometer measurements taken in an approximately 25 mm (1") turbulent boundary layer set up on a flat plate at a free stream speed near 29.9 m/sec (98 ft/sec). These measurements were made to assess the applicability and accuracy of laser doppler anemometry (LDA) in boundary layer flows. Results indicated that LDA compared well with both hot wire and pressure measurement methods and that for all three measurement systems vertical positioning of the probe was the major factor limiting accuracy.

For the measurements reported in Reference [3], the laser beam diameter was approximately 2.7 mm upon leaving the transmitting optics. This served to limit the minimal obtainable distance from the wall to roughly 1.25 mm. A reasonable goal for boundary layer measurements is to approach the wall to within 0.25 mm or about five times closer than we had obtained. To reduce the beam clipping problem and move closer to the wall, the entire optical

assembly was shimmed so as to be at a 1° angle to the flat plate. Typical results are shown in Figure 1. The comparison between LDA and hot wire measurements at 0.125 mm is noteworthy. Clearly, from Figure 1, placing the optical package at a 1° angle to the blades will permit LDA measurements to at least 0.125 mm. This technique has been incorporated into the cascade design. It should be clearly noted here that for distances on the order of 0.125 mm from the wall, vertical positioning may be no better than ±20%. In fact it is common practive in boundary layer work to back calculate the absolute position by shifting the linear velocity profile near the wall so as to get zero velocity at the wall [4].

2. Reduction of Cascade Tunnel Turbulence Intensity

As reported in June 1980 [2], the turbulence intensity at the inlet to the test section of the NASA cascade tunnel was found to be approximately 0.18% ±10% over a speed range of 80 to 140 ft/sec. These measurements, taken with a tungsten, cylindrical hot wire sensor 0.00012 inches in diameter in conjunction with a Disa Model 55D01 constant temperature anemometer system, are in reasonable agreement with the 0.165% reported by Gearhart and Ross [5]. Both measurements are, however, higher than the 0.1% which is generally felt to be desirable for low turbulence work.

It was postulated in reference [2], that the higher than expected turbulence level was caused by the unconventional position of the honeycomb; downstream of the turbulence reducing screens in the settling section (see Figure 2). In an effort to reduce the intensity then, the 1/4 in. cell size honeycomb, 16 in. thick, was removed from the settling section, and a 1/8 in. cell size honeycomb, 6 in. thick, was added just downstream of the rubber coupling (Figure 2). Turbulence intensity measurements were conducted in the same manner as reported in reference [2]. These measurements indicate a turbulence intensity of 0.07% ±10%, an acceptable level.

3. Initiation of Cascade Testing

A redesign of the cascade facility, for the purpose of incorporating the requirements of the LDA system into the design was completed. The redesigned facility is shown in Figure 3. Mr. Nelson Sanger, NASA Contract Manager, has provided the initial blade design. These blades, double circular arc design and designated DCA4 are shown in Figure 4. The initial angle of incidence will be 53°.

Major features of the cascade design include:

a. The use of diverging walls instead of suction for two dimensionality control

b. The angle of incidence being changed by rotating the blade pack and

c. The laser traversing system (with the optical package at one degree to the blade surface) being tied to the blades circular arc (e.g. one pivot point for each blade arc.)

The use of diverging walls to control two-dimensionality was felt to be novel enough in cascades to warrant testing the concept separately. To this end the first year's cascade testing has been divided into two phases. In phase I, the cascade tests of Gearhart and Ross [5,6] will be redone using their existing blades with diverging walls replacing suction. Comparison against their results should provide an excellent test of the diverging wall concept. Phase I testing is currently underway.

Phase II will involve the detailed cascade testing and boundary layer measurements on the new double circular arc blades. Hardware for the tests will be complete by 6/15/81, with blade construction and instrumentation scheduled to be complete in early July.

References

[1] Deutsch, S., Semi-Annual Progress Report for NASA Grant NSG-3264, January 1980.

[2] Deutsch, S., Semi-Annual Progress Report for NASA Grant NSG-3264 June 1980.

[3] Deutsch, S., Semi-Annual Progress Report for NASA Grant NSG-3264, January 1981.

[4] Purtell, P., Private Communications, February 1981.

[5] Gearhart, W. S. and Ross, J. R., "A Subsonic Cascade Test Facility-An Aid to Hydrodynamic Blade Design," ORL Internal Memorandum, File No. 506-02, March 13, 1970.

[6] Gearhart, W. S., and Ross, J. R., "Two Dimensional Cascade Tests of a Compressor Blade Designed by the Mean Streamline Method," ORL Internal Memorandum, File No. 71-32, February 22, 1971.

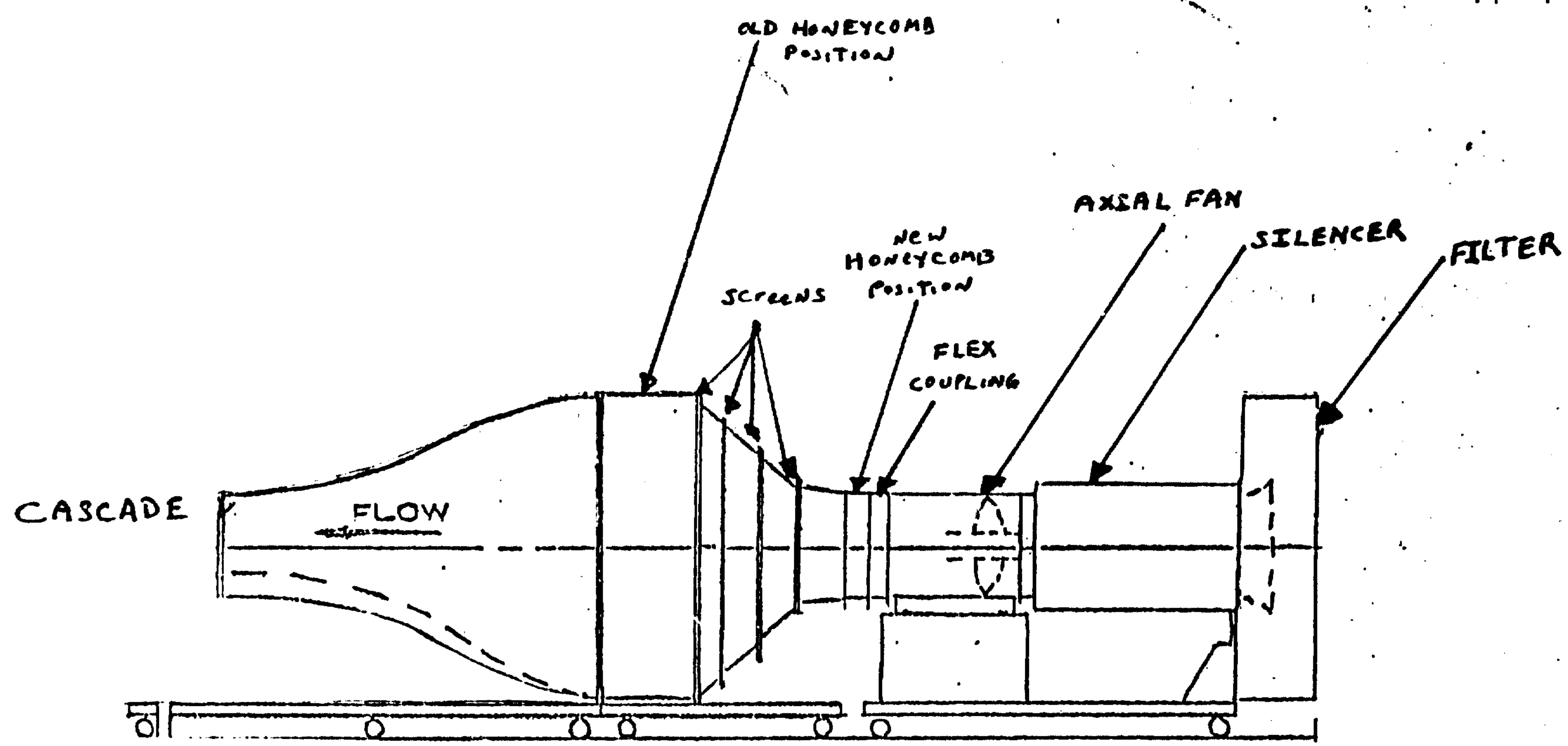

Figure-1: Schematic of NASA Cascade Tunnel
(NOT TO SCALE)

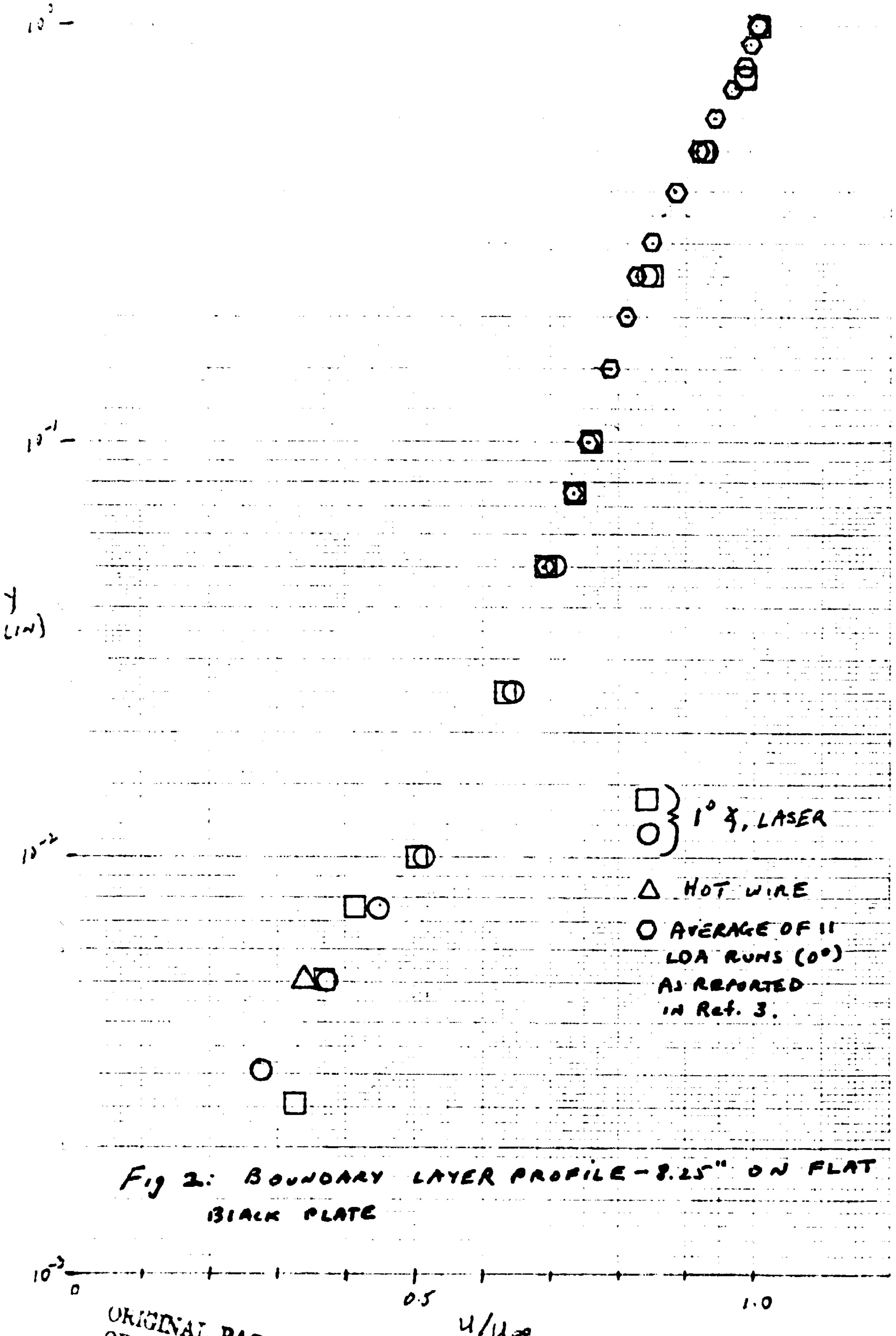

Fig 2: BOUNDARY LAYER PROFILE – 8.25" ON FLAT BLACK PLATE

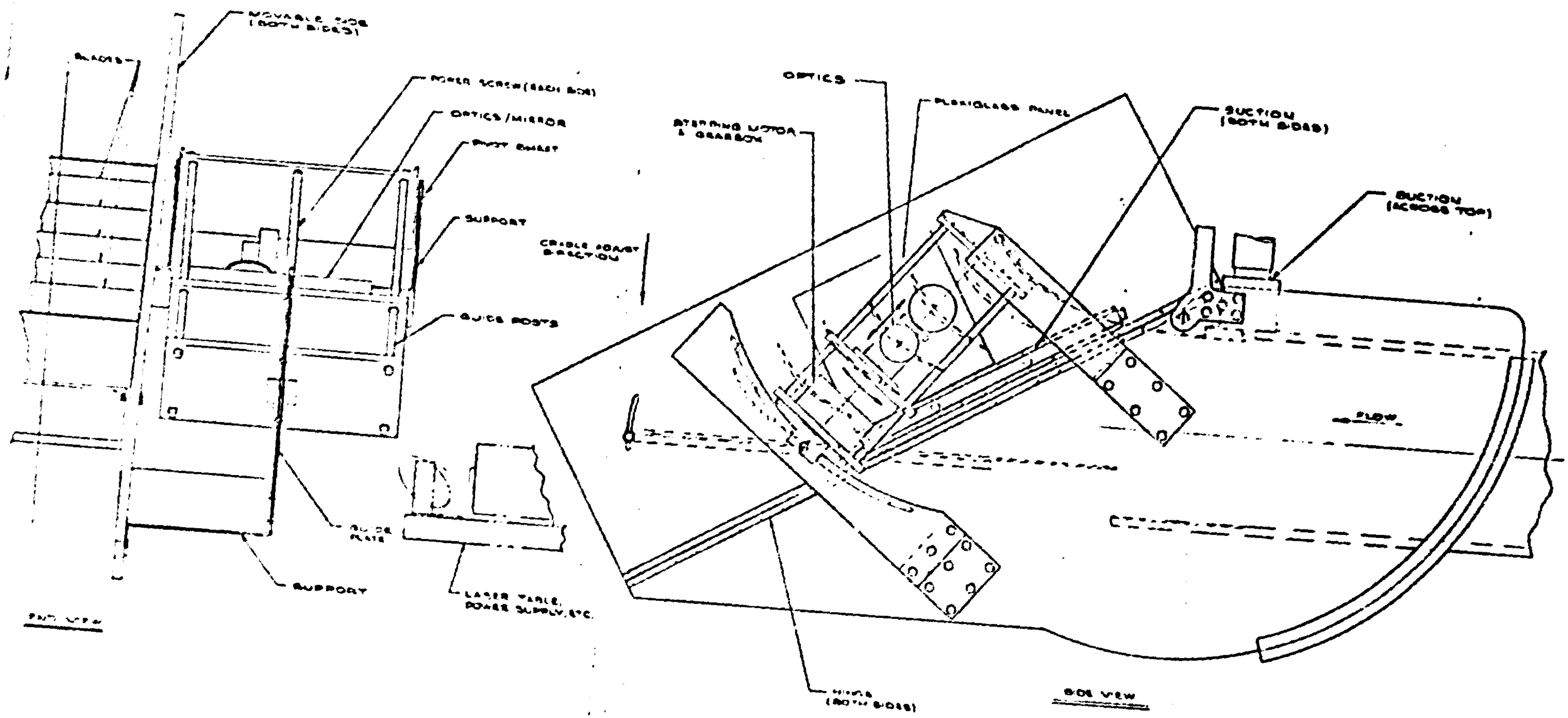

Figure 3 - New CASCADE Section

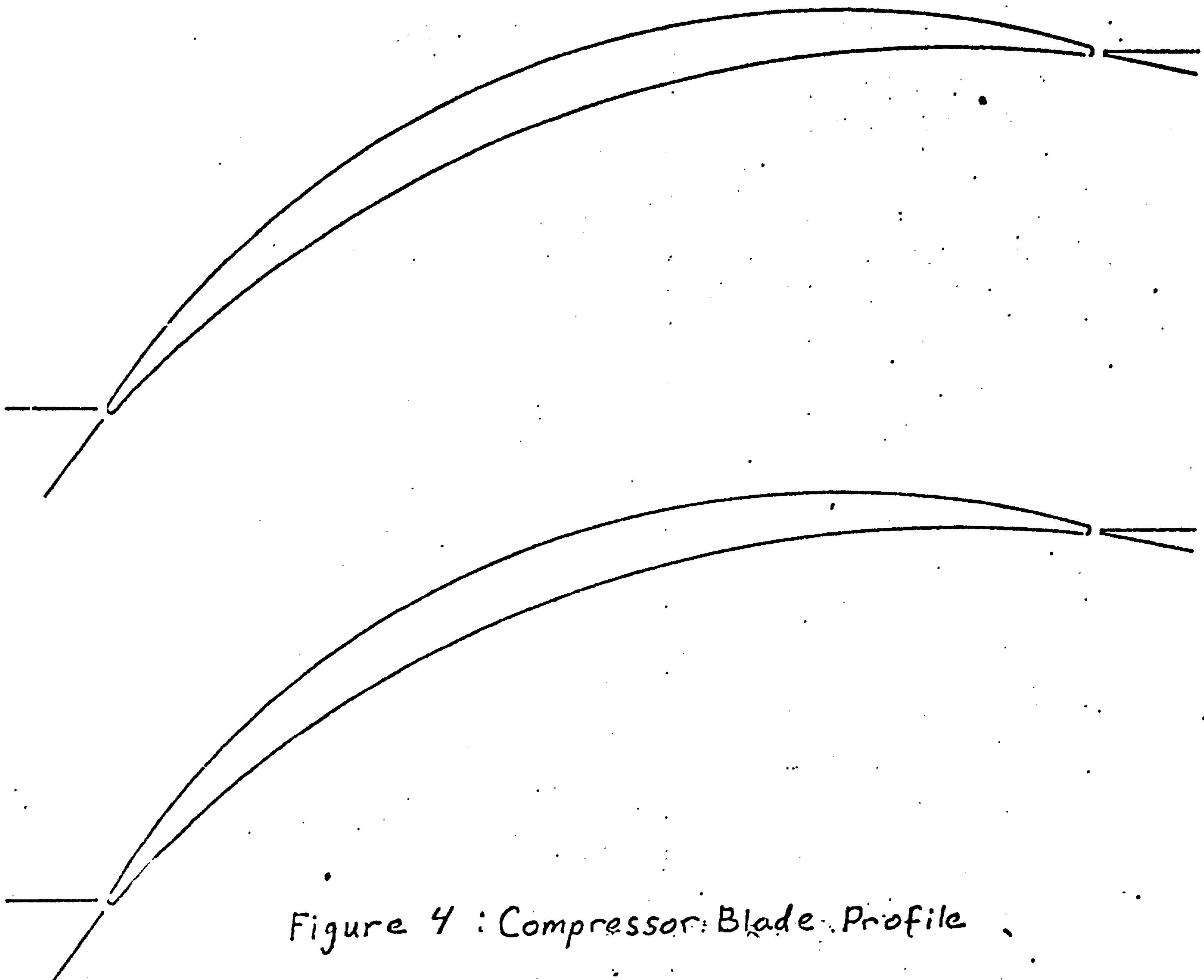

Figure 4 : Compressor Blade Profile